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Dredging Research Technical Notes

Monitoring Considerations for Capping

Purpose

This technical note describes monitoring considerations for capping projects, including establishing monitoring objectives, designing monitoring programs/plans, monitoring approaches, and monitoring equipment and techniques.

Background

Some dredged material may be unsuitable for unconfined open-water disposal because of potential contaminant effects on benthic organisms. Capping contaminated dredged material with a layer of clean material is considered an appropriate contaminant control measure for benthic effects in Corps dredging regulations (33 CFR 335-338) and supporting technical guidelines (Francingues and others 1985) and is recognized by the London Dumping Convention as a management technique to "rapidly render harmless" otherwise unsuitable materials.

Guidelines are available on planning and design concepts (Truitt 1987a, 1987b), design requirements (Palermo 1991a), site selection considerations (Palermo 1991b), and equipment and placement techniques (Palermo 1991c) for capping projects. This note supplements and updates available guidance by describing monitoring considerations for capping projects.

Additional Information

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Introduction

Capping is the controlled, accurate placement of contaminated dredged material at an open-water disposal site, followed by a covering or cap of clean isolating material. In this note, the term "contaminated" refers to material found to be unacceptable for unrestricted open-water placement because of potential contaminant effects, while the term "clean" refers to material found to be acceptable for such placement.

Level bottom capping (LBC) may be defined as the placement of a contaminated material on the bottom in a mounded configuration and the subsequent covering of the mound with clean sediment. Placement of contaminated sediments on a level bottom usually results in a mounded central deposit surrounded by a thinly layered, tapering flank deposit that can cover an area several times larger than that of the central deposit. Contained aquatic disposal (CAD) is similar to LBC but with the additional provision of some form of lateral confinement (for example, placement in bottom depressions or behind subaqueous berms) to minimize spread of the materials on the bottom.

Design Requirements for Capping

The development and execution of a monitoring program is a design requirement for capping operations. However, all components of design for a capping project are strongly interdependent. The major design requirements for capping and the sequence in which they should be considered are fully described in *Dredging Research Technical Notes* (TN) DRP-5-03 (Palermo 1991a). Monitoring should be considered within the context of the overall design requirements for the project as described in TN DRP-5-03.

Need for Monitoring

Capping involves open-water placement of dredged material which has been tested and determined unacceptable for uncontrolled open-water placement because of potentially unacceptable levels of benthic toxicity or bioaccumulation of contaminants in benthic organisms. Capping acts as a control measure for such effects by isolating the contaminated material from the benthic environment. Monitoring is required during and following placement of the contaminated and capping materials to ensure that an effective cap has been constructed (which may be defined as construction monitoring). Monitoring may also be required to ensure that the cap, as constructed, will be effective in isolating the contaminants and that long-term integrity of the cap is maintained (which may be defined as long-term monitoring).

Because capping is a control measure for potential benthic effects, this technical note does not describe water-column processes or the water-column contaminant pathway during the placement of contaminated material before capping. If the contaminated material has potential for unacceptable water-column impacts during placement, other control measures to offset those impacts and additional monitoring of water column processes will be necessary.

This technical note also does not describe aspects of open-water site monitoring pertaining to site designation or specification or to direct physical effects of placement. Such monitoring would be considered in the context of the overall site selection process (Palermo 1991b). Interim guidance on prediction and monitoring of uncapped dredged material in open waters was compiled in a DRP Technical Area 1 notebook distributed in a 1990 workshop (US Army Engineer Waterways Experiment Station 1990).

Design of Monitoring Programs and Plans

The design of monitoring programs for any project should follow a logical sequence of steps. Several excellent publications containing general guidance for monitoring in marine environments and specific guidance on physical and biological monitoring at aquatic sites for site designation/specification and for permit compliance are available (Marine Board, National Research Council 1990, Fredette and others 1990a, Fredette and others 1990b, and Pequegnat, Gallaway and Wright 1990). These references should be consulted in developing appropriate monitoring plans for capping projects which suit the site and material specifics.

Fredette and others (1990a) outlines five steps in developing a physical/biological monitoring program for open-water dredged material placement which should also be followed in developing a monitoring program for capping projects:

- Designating site-specific monitoring objectives.
- Identifying components of the monitoring plan.
- Predicting responses and developing testable hypotheses.
- Designating sampling design and methods (to include selection of equipment and techniques).
- Designating management options.

Fredette and others (1990a) recommends prospective monitoring which consists of observations or measurements that determine whether site conditions conform to a predetermined standard. Unacceptable adverse effects or unreasonable degradations are also defined before sampling is

begun. This action contrasts with retrospective programs in which the magnitudes, types, and areal extent of adverse impacts are not defined until after sampling is underway and data are interpreted. The physical and chemical thresholds which result in undesirable biological responses or effects must be determined and the potential impacts of the disposal predicted.

Numerical models for predicting the short-term and long-term fate of dredged material (Johnson 1992 and Scheffner 1992) can help to define physical behavior during placement, the magnitude of storm events that could cause erosion, potential erosion amounts, and transport direction. Thus, these numerical models can be useful in planning a monitoring program.

The monitoring program should be multitiered, as suggested by Fredette and others (1990a). Each tier has its own unacceptable environmental thresholds, null hypotheses, sampling design, and management options should the thresholds be exceeded. These thresholds are best determined by a multidisciplinary advisory group whose technical advice is sought in organizing and conducting the monitoring program. Table 1 outlines a sample tiered monitoring program for capping projects. Each step in developing a capping monitoring program is discussed in more detail in the following paragraphs.

Monitoring Objectives

Setting attainable and meaningful objectives is a necessary first step in designing any monitoring program/plan. Appropriate objectives for a capping monitoring program/plan include the following:

- Define the areal extent and thickness of the contaminated material deposit to guide placement of the capping deposit.
- Define the areal extent and thickness of the cap.
- Determine that the desired capping thickness is maintained.
- Determine that the cap is effective in isolating the contaminated material from the benthic environment.

Components of the Monitoring Plan

The components of the monitoring plan should be directly tied to the objectives and include physical, chemical, and biological components. In identifying components and processes, it should be noted that biological responses are a direct result of physical and chemical alterations due to the placement operation. This fact provides a logical basis for establishing an appropriate tiered monitoring program.

Table 1

Sample Tiered Monitoring Program for a Capping Project

Monitoring Program Components	Monitoring Frequency	Threshold	Management Options: Threshold Not Exceeded	Management Options: Threshold Exceeded
Consult site designation surveys, technical advisory, committee and Environmental Impact Statement for physical and chemical baseline conditions	--	--	--	--
Tier 1 • Bathymetry • Subbottom profiles • Side-scan sonar • Surface grab samples • Cores • Water samples	Pre, Post Placement, Annually	• Mound within 5 ft of navigation hazard • Cap thickness decreases 0.5 ft • Contaminant exceeds limit in sediment or water sample	• Continue to monitor at same level • Reduce monitoring level • Stop monitoring	• Go to next tier • Stop use of site • Increase cap thickness
Tier 2 • Bathymetry • Subbottom profiles • Side-scan sonar • Sediment profile camera • Cores • Water samples • Consolidation instrument	Quarterly to semiannually	• Cap thickness decreases 1 ft • Contaminant exceeds limit in sediment or water sample	• Continue to monitor at same level • Reduce monitoring level	• Go to next tier • Replace cap material • Increase cap thickness • Stop use of site
Tier 3 • Bathymetry • Subbottom profiles • Side-scan sonar • Sediment profile camera • Consolidatron instrument • Surface grab samples • Cores • Water samples • Tissue samples	Monthly to semiannually	• Cap thickness decreases 1 ft • Contaminant exceeds limit in sediment or water sample • Contaminant exceeds limit in tissue	• Continue to monitor at same level • Reduce monitoring level	• Replace cap material • Increase cap thickness • Stop use of site • Change cap sediment • Redredge and remove

Physical processes of interest include the extent and thickness of the contaminated and capping layers during placement operations, potential erosion of these deposits due to currents and wave action, and consolidation of the deposits and underlying sediment layers. Erosion and consolidation processes will dictate the long-term thickness of the cap. The components of a monitoring plan to address these processes would include periodic precision bathymetry, perhaps supplemented with sediment profiling camera surveys, settlement plates, or other instrumentation.

Chemical processes of interest include potential mixing of contaminated material with the clean capping material during the construction phase, and perhaps in the long-term due to bioturbation, and the potential migration of contaminants upward through the cap due to consolidation or diffusion. The components of the monitoring plan addressing these processes would include sediment cores for chemical analysis of sediment or interstitial water to define the chemical profile of the contaminated and clean capping layers. Additional cores taken over time at the same stations would assess any upward contaminant migration.

Biological processes of interest include the potential for contaminant effects (that is, toxicity and bioaccumulation) should contaminant migration occur or should the integrity of the cap be compromised. Components of monitoring which address these processes include sampling and analysis of benthic organisms which would colonize the site following completion of capping.

Developing Testable Hypotheses

Testable hypotheses should be established which are tied to critical threshold levels which, when exceeded, trigger a higher monitoring tier or implementation of a management action. Development of reasonable and testable hypotheses requires a prediction of the end result of the various processes which may occur at the site. A null hypothesis is developed (that is, that there is no significant difference between predicted and observed conditions), and if the threshold is exceeded, the null hypothesis is rejected. Tiers should be structured so that potential problems can be detected early. Often physical monitoring may be the best or primary tool in the lowest tier, but biological or chemical tools may have appropriate roles in the lowest tier as well. The key is to get relatively rapid, inexpensive, and interpretable results.

Construction Monitoring

Monitoring to assure that placement occurs as designed may include baseline, postplacement of the contaminated material, interim, and postplacement of capping material surveys. Baseline surveys would consist of determining the existing bathymetry of the site to determine changes in depth resulting from disposal. The postplacement monitoring

of the contaminated material determines where the contaminated sediments have been placed so that a final plan of cap discharge locations can be developed. Postplacement sampling of the contaminated material is also needed as baseline for cap thickness determinations based on bathymetry. Interim surveys may be used in large projects to determine where sufficient cap has been placed and where additional material should be placed. Finally, postplacement monitoring of the capping material is used to confirm the final cap thickness.

Monitoring for Long-Term Effectiveness

The principal long-term concerns for capped deposits are whether the cap remains in place or erosion is occurring and whether the contaminants remain within the contaminated layer or are being transported to the sediment surface layer or water column. Erosion can occur either due to daily tidal currents or as a result of storm-related surges or waves. Potential mechanisms for contaminant movement through the cap include pore-water movement, diffusion, and biological sediment mixing (bioturbation).

Monitoring approaches for these concerns include sequential bathymetric surveys to determine changes in deposit height, surface sediment chemistry samples, sediment and pore-water chemistry profiles from cores, sediment physical structure from cores, benthic community structure, and contaminant tissue concentrations of mound-resident benthic species. These and other monitoring techniques discussed below can all be considered within the framework of a tiered monitoring plan and would be conducted on time intervals ranging from months to years.

Monitoring Techniques and Equipment

Selection of the types of samples or observations to be made, the equipment to be used, the number of samples or observations, and other factors is highly project dependent. Fredette and others (1990b) and Hands (in preparation) give guidelines on available equipment and techniques.

Monitoring programs may consist of only physical measurements, including bathymetry, cap thickness, sediment physical properties (for example, grain size distribution and density), wave and current conditions, among other measurements. Depth sounders, side-scan sonar and subbottom profilers, sediment sampling and coring devices, sediment profiling cameras, and instruments for measuring sediment engineering properties are required to make these physical measurements.

Navigation and positioning equipment are needed to accurately locate sampling stations or survey tracks in the disposal site area. Calibrated Loran C equipment provides accuracies of 50 to 300 ft typically,

although certain locations may be less accurate due to interference problems. Short-range microwave equipment has accuracy of +/- 3 ft and is recommended for the kind of repeatability necessary for accurate survey comparisons. Taut wired buoys are also excellent for marking disposal locations and as a reference for sampling station locations. The satellite-based Global Positioning System (GPS) will soon replace microwave systems as the high-accuracy positioning system (1-3 m) for most applications.

Precision bathymetric surveys are perhaps the most critical monitoring tool for capping projects. Such surveys allow determination of the location, size, and thickness of the contaminated material mound or deposit and cap. A series of surveys should be taken before placement of contaminated material, immediately following (and perhaps during) placement of the contaminated material, and immediately following placement of the cap. The difference in bathymetry as measured by the consecutive surveys yields the location and thickness of the deposits. Acoustic instruments, such as depth sounders (bottom elevations accurate to +/- 0.6 ft), side-scan sonar (mapping of areal extent of sediment and bedforms), and subbottom profilers (which measure internal mound and seafloor structure), are used for these physical measurements.

The attainable accuracy of bathymetric surveys limits the area and thickness of the deposit which can be detected. Limits of accuracy are governed by a variety of factors including accuracy of positioning systems, water depth, wave climate, and other factors. Engineer Manual (EM) 1110-2-1003 (U.S. Army Corps of Engineers 1991) contains detailed information on hydrographic survey equipment and techniques and should be consulted in estimating the accuracy limitations of surveys. Other monitoring tools, such as side-scan sonar or sediment profiling cameras, must be used to detect thinner deposits of contaminated and capping material.

Bathymetric monitoring of deposits to determine sediment losses needs to be coupled with an understanding of consolidation processes. Consolidation that occurs in the cap, contaminated sediment, and the original base material within 6-12 months of disposal can result in substantial reductions in mound height (Brandes and others 1991, Poindexter-Rollings 1990) that could mistakenly be considered erosion.

The sediment profiling camera (SPC) is a recently developed tool which can be used to detect thin layering within sediment profiles. To obtain an image of sediment layering and benthic activity by penetrating to a depth of 20 cm, the SPC is lowered to the bottom and activated. As with bathymetric surveys, the SPC approach also has limits in its ability to detect the extent and thickness of deposits. The limiting depth of penetration limits the thickness which can be detected, but the SPC can be used in conjunction with bathymetric surveys to define the full range and extent of deposit thicknesses. The SPC is extremely effective for mapping the extent of the flanks of contaminated sediment around the

central portion of the mound. Knowing their extent is critical to successful capping because these flanks can account for an area several times larger than that of the central mound and can include 20-40 percent of the sediment mass.

Sediment samples can be taken using grab samplers or coring devices to determine both physical and chemical parameters. A core would generally be required to sample the full thickness of a cap layer and the underlying contaminated material. Conventional boring techniques, vibracore samplers, and a variety of gravity coring devices may be suitable.

Various other instruments and approaches may be considered to gain needed information regarding the physical condition and processes occurring at capping sites. These include settlement plates (which must be monitored by divers), remotely operated instruments, or divers with photography and video cameras to obtain data on site conditions.

Biological monitoring may include sampling of fish, shellfish, and benthic organisms. Fish and many shellfish are mobile and, therefore, data using these organisms is more difficult to relate to cause and effect. Sampling design using such mobile species needs to consider carefully the effects of scale and migration dynamics. Most often disposal mounds or sites are inconsequential with respect to the ranges of such species and detecting or linking any changes in a species to placement activities may be unlikely.

Benthic organisms are usually sedentary and often are considered good indicators of the effects of physical and chemical alterations of the environment. Benthic sampling devices include trawls, drags, box corers, and grab samplers. Trawls and drags are qualitative samplers which collect samples at the bottom interface and, therefore, are good for collecting epifauna and shallow infauna (top few centimeters). Quantitative samples are usually obtained with box corers and grab samplers. Generally these samplers collect material representing 0.02 to 0.5 sq m of surface area and sediment depths of 5 to 100 cm.

Sampling of tissues of marine biota which colonize the mound also needs to be carefully considered. Typically the chemical analyses require about 15-30 g (wet weight) of tissue per replicate. Unless the particular region has large-bodied resident species that are easily collected, a day or more of field collection per station may be required to obtain the necessary sample requirement. Tissue sampling is also complicated by the natural variation of benthic populations in both space and time. In some years the target species may be very abundant, while in other years the species can be rare. These factors can result in very large monitoring costs or produce data which are of limited value.

Chemical gradients or changes in the distribution of contaminants within the mound can be monitored, but will require an understanding

of the baseline heterogeneity of contaminants within both the contaminated deposit and the cap. For example, the contaminant levels within the contaminated deposit can be expected to range from hot spots to concentrations that are similar to or even below the concentrations within the cap. This situation reflects typical heterogeneity within the original deposit and cleaner underlying layers of the channel or harbor. Thus, while it may be possible to detect large transitions, gradients may be much more difficult to observe.

Designating Management Actions

If thresholds are exceeded, management actions should be predetermined. Management options in early tiers could include increasing the level of monitoring to the next tier, the addition of more sediment to form a thicker cap, or stopping use of the site. Management options in later tiers could include stopping use of the site, changing the cap material, or adding a less porous material in cases where contaminant transport due to biological or physical processes is occurring. For caps that are experiencing erosion, additional cap material can also be added, although it may be advisable to choose a coarser material (coarse sand or gravel) to provide armoring. In cases where extreme problems are encountered, removal of the contaminated material and placement at another site could be considered.

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